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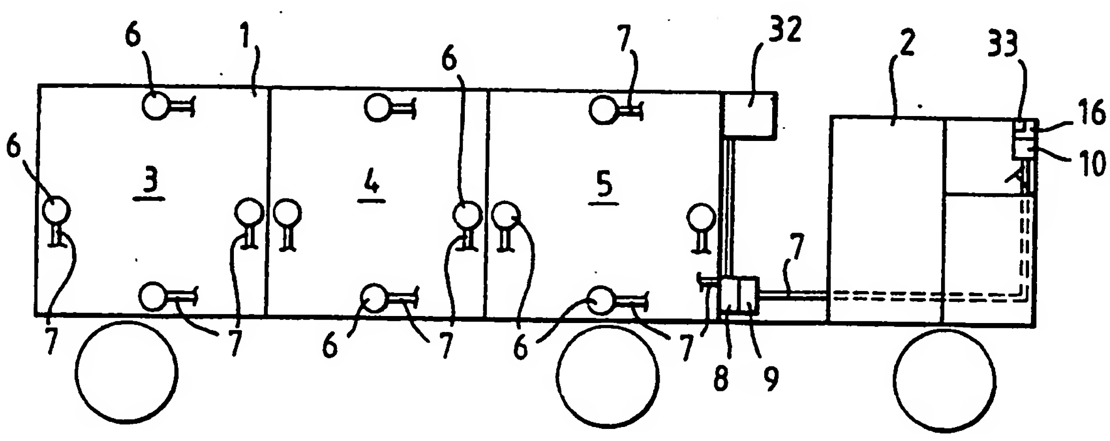
(58) Field of search
G1N

(54) Temperature monitoring system

(57) A temperature monitoring system for a temperature controlled container (1) comprises one or more temperature sensors (6) mounted so as in use to sense the temperature of the interior of the container (1) and to produce an electrical signal representative of the temperature, and digital data logging means responsive to said electrical signals to log the temperature history of the container over a period of time for subsequent retrieval. Displays and alarms can also be provided to indicate unacceptable temperatures. A printed record of the temperature history of seveal compartments of the container covering a journey can be provided.

Fig. 1.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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Fig. 1.

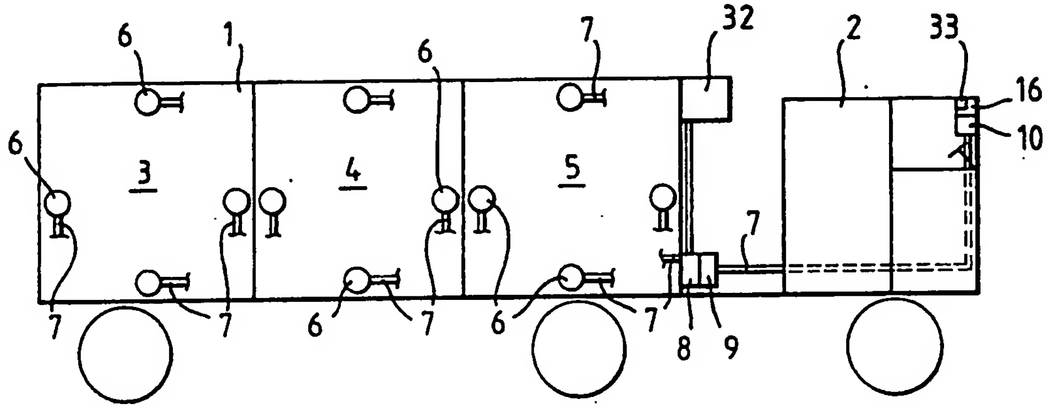

Fig. 3.

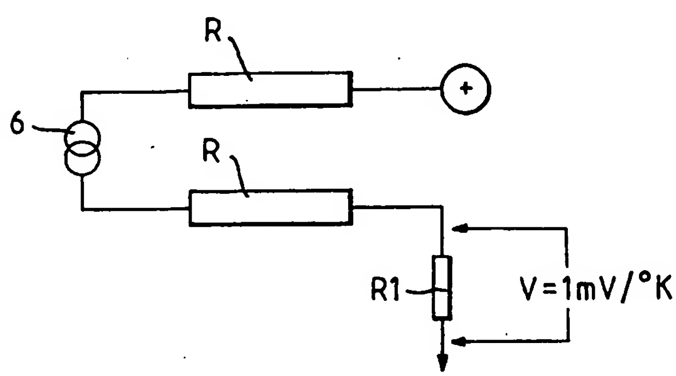

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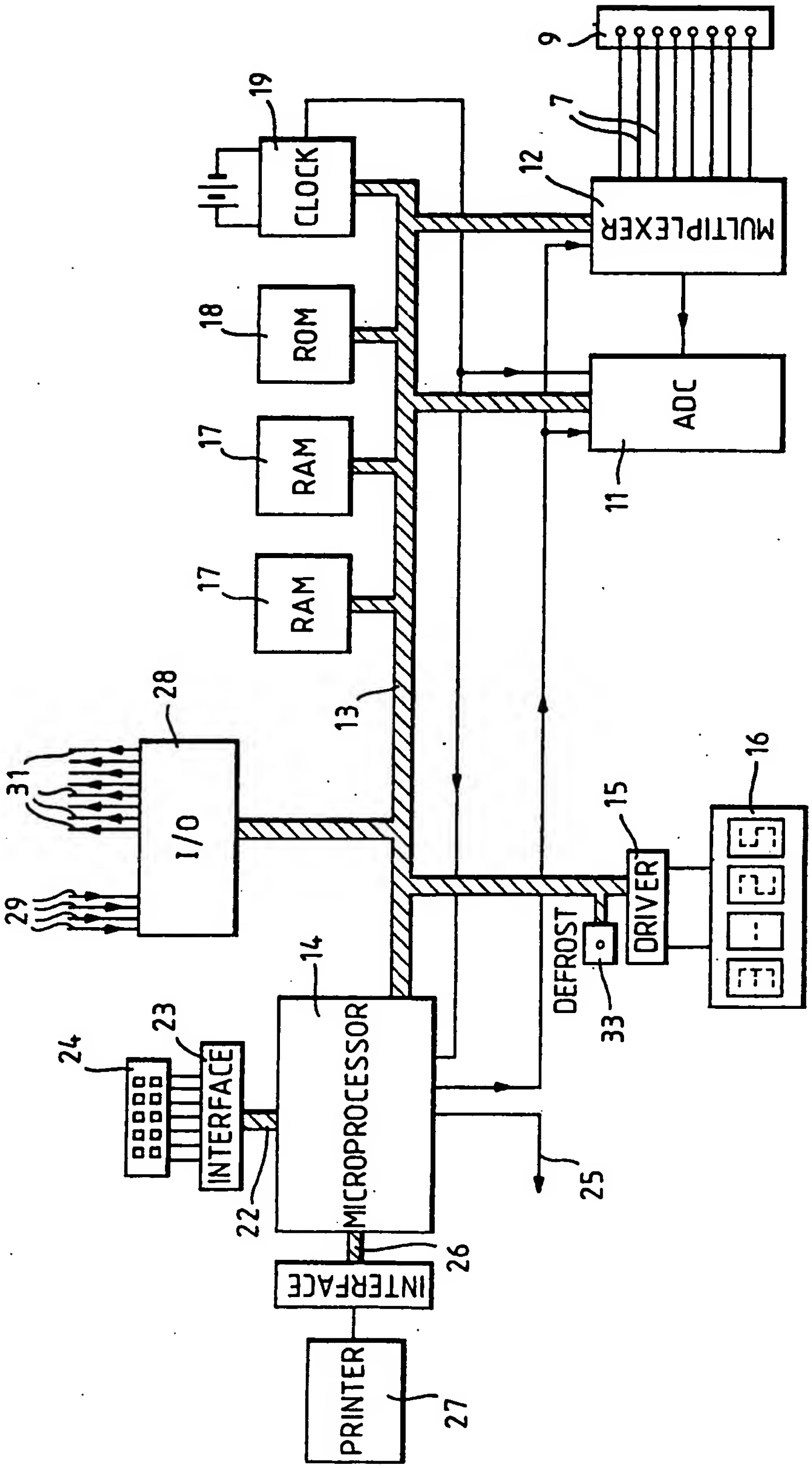
Fig. 2.



CHANNEL STATUS
CHANNEL 1
ACTIVE
UPPER -20
LOWER -55
CHANNEL 2
ACTIVE
UPPER -20
LOWER -55
CHANNEL 3
ACTIVE
UPPER -20
LOWER -55
CHANNEL 4
ACTIVE
UPPER +00
LOWER -20

Run No. 0002
VEHICLE No. 0940
STORE INTERVAL 15 MIN
DEF. TIME 20 MIN

START 18:20 01/11
END 17:39 02/11

Fig. 4.

CHANNEL			
1	2	3	4
+04	+00	-08	-04
+04	-01	-09	-05
+03	-02	-10	-06
+03	-02	-11	-07
+03	-03	-11	-07
+02	-03	-11	-08
+02	-04	-12	-08
+02	-04	-12	-09
+01	-04	-13	-09
+01	-05	-13	-10
+01	-05	-14	-10
+01	-03	+03	-01
+01	-05	-13	-09
+01	-06	-14	-10
+00	-07	-14	-11
+00	-07	-15	-12
+00	-08	-15	-12
+00	-08	-16	-13
+00	-09	-16	-13
-01	-09	-16	-13
-01	-09	-17	-14
-01	-10	-17	-14
-01	-10	-17	-15
-01	-10	-18	-15
-01	-11	-18	-15
-01	-11	-18	-16
-02	-11	-18	-16
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SPECIFICATION

Temperature monitoring system

This invention relates to temperature monitoring systems and has particular, but not exclusive, reference to such a system for a refrigerated container in the form of an articulated vehicle, for example.

Refrigerated articulated vehicles are often fitted with a temperature monitoring system in the form of one or more temperature sensors connected to one or more temperature gauges which are analogue devices and merely indicate the sensed temperature at a given instant. The gauges are mounted externally of the refrigerated container and in the case of an articulated vehicle are located on the container for viewing by the driver through a rear view mirror. These known temperature measuring systems are unsatisfactory in that they provide no indication of the range of temperature to which the container has been subjected over a period of time and the monitoring of the temperature gauge(s) by the driver is not readily accomplished and in any event is entirely at his discretion. A given container can hold foodstuffs, or other goods requiring temperature control, worth large sums of money, whereby it is important to exercise close control over the temperature of the goods, for example during transit, to ensure that they are not spoiled and to be able to demonstrate to the recipient of the goods that the latter have not been subjected to any adverse temperature.

According to the present invention a temperature monitoring system for a temperature controlled container comprising one or more temperature sensors mounted so as in use to sense the temperature of the interior of the container and operable to produce an electrical signal representative of the sensed temperature, and data logging means responsive to said electrical signals to log the temperature history of the container over a period of time for subsequent retrieval.

The term "container" as used throughout this specification is intended to cover any form of temperature controlled locality irrespective of whether it is transportable in as much as the present invention is applicable to any form of area or enclosure the temperature of which is controlled and requires monitoring.

The data logging means may be in the form of memory means under the control of a microprocessor, which memory means calculate and store the temperatures sensed by the or each temperature sensor, analogue-to-digital coverter means being employed between the or each sensor and the microprocessor. The system may further comprise display means operable to display the temperature sensed by the or each sensor and integrated or separate alarm means may be provided to warn when a temperature, or range of temperatures has not been met or has been exceeded. Furthermore, the system may comprise printer means connectible to the data logging means and operable to provide a hard copy of the temperature history of the container.

In a preferred embodiment of the present invention for use with a refrigerated articulated vehicle the system has a plurality of channels, whereby one or more temperature sensors can be employed with each of a plurality of sections of the container which may need to be kept at different temperatures appropriate to fresh, chilled and frozen food, for example. Each temperature sensor is of the type in which the electrical output current is proportionl to temperature and this is an extremely important feature because it gives rise to significant advantages over voltage proportional sensors. Firstly, the output signals from the current proportional temperature sensors are not degraded by cable resistance and connector resistance, nor are they sensitive to electrical noise. This is a considerable advantage when the distance between sensor and data logging means can be up to 20 metres in the case of an articulated vehicle. Secondly, the current proportional sensors give a readily available average temperature for the container overall or a section thereof.

In the preferred embodiment the logging means is in the form of a microprocessor which can be programmed externally by a keypad, for example, to allocate channels, set alarm limits for each channel, set the temperature recordal interval, and record driver, vehicle and journey details. The system includes a real time clock, including day and month, and is powered from the vehicle battery. The temperature of each channel is displayed sequentially on a display device which can be arranged to flash on each channel in connection with which an alarm condition has been sensed, and a given channel can be held on the display.

A temperature monitoring system in accordance with the present invention and as applied to a refrigerated articulated vehicle will now be described in greater detail, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a diagram of the vehicle showing the basic components of the system,

Figure 2 is a block diagram of the system,

Figure 3 is a diagram of a temperature sensor of the system of Fig. 1, and

Figure 4 is an illustrative printout produced by the system.

Fig. 1 shows a conventional articulated vehicle having a refrigered trailer 1 pulled by a so-called tractor 2 and split into three storage sections 3, 4 and 5. Each storage section 3, 4 and 5 has four temperature sensors 6

mounted therein, preferably one on each of two pairs of opposed sides, with the sensors connected by respective twisted pair cables 7 to a connector 8 on the front end of the trailer. A complementary connector 9 is removably attachable to the connector 8 and continues the cables 7 to a control unit 10 for the system which is shown in detail in Fig. 2. The connector 8, 9 is provided in order for the tractor 2 to be released from a given trailer and subsequently reconnected to the same trailer or a different trailer.

The cables 7 between the connector 9 and the system control unit 10 maybe accommodated within a protective sheath and each sensor 6 is of the current proportional type and may be of the AD 590 series manufactured by Intersil. The AD 590 sensor is a laser trimmed semiconductor device the output of which is a current proportional to absolute temperature (degrees Kelvin) and provided the voltage across the sensor lies in the range 4 to 30 volts DC, then the output current is directly proportional to absolute temperature at 1 $\mu A/^{\circ}K$. Each sensor 6 is secured by epoxy resin within a copper tube (not shown) and mounted in thermal contact with the interior of the appropriate trailer section 3, 4, 5 which may include mounting within the skin thereof.

With the use of a current proportional sensor the distance thereof from the temperature measuring system (in the present case the system control unit 10) is relatively unimportant in that the electrical resistance R (Fig. 3) of the conncting cable has no effect on the sensor current output since any voltage drop across R is ignored by the sensor. For example with a 12 volt supply and a temperature of 300°K (27°C) the resistance R of each cable of the twisted pair associated with each sensor 6 could be 500 K ohms without causing any degradation of the sensor output. The output of each sensor 6 is measured across a precision resistor R1, as indicated in Fig. 3, by an anlogue-to-digital converter (ADC) 11 which forms part of the control unit 10 as seen in Fig. 2. With the resistor R1 of 1K ohm the potential difference across that resistor is $1mV/^{\circ}K$ and as this voltage is generated essentially at the input of the ADC 11 which has a low input impedance, then the signal is not degraded before being converted to digital form.

Turning now to Fig. 2, the sensor output signals are applied to the ADC 11 via an analogue multiplexer 12 and the output of the ADC is connected to a data bus 13 which serves a microprocessor 14, a driver 15 for a four-digit adjustable LED display 16 having a brightness control and "hold" switch (not shown), two random access memories (RAM) 17, a read only memory (ROM) 18, and a real time clock 19 which produces the day and month as well as time. The output of the clock 19 is connected to both the ADC 11 and the microprocessor 14, and the multiplexer 12 is connected to the data bus 13 in order that it can be controlled by the microprocessor. The driver 15 is an LSI decoder driver providing non-multiplexed drive to the display 16 to reduce the likelihood of airborne interference.

The microprocessor 14 is provided with an input 22 connected to a keypad interface 23 to which a keypad 24 is removably connectible, and has two output lines 25 and 26, the former providing a serial output port for down dumping of stored data into a memory module, modem, computer or other device to provide a stored record externally of the control unit 10. The output line 26 is applied to a printer 27 which is integral with the display 16 (but not necessarily so) and is a 24-column impact printer with removable ribbon and paper. Easy access to the printer 27 is provided by a quick-release panel (not shown). The printer is driven by a single chip controller based on a mask programmed micro-computer.

The data bus 13 also has connected to it a digital input/output device 28 having four input lines 29 and eight output lines 31. The input lines 29 are volt-free contacts and can be connected to the trailer doors, for example, in order to monitor the opening and closing thereof. The output lines 31 are of the open collector type and can be used for control purposes. For example the output lines 31 can be connected to relays (not shown) for controlling the trailer compressor unit 32 (Fig. 1) or other device in the event of a sensed temperature being too high or too low. An external visual and/or audible alarm may be connected to an output line 31 to warn when an alarm condition exists in (addition to the flashing display already referred to), such an alarm being useful when the vehicle is parked and the driver is not in the cab. An inbuilt function of the output stage is to provide an internal audible alarm on the defrost function.

In use of the system with a fleet of articulated vehicles, for example, each trailer is fitted with the required number of sensors depending to some extent on whether it is sectionalised or whether it provides one large storage space, and each tractor is fitted with a control unit 10, a display 16 and a printer 27, there being free interchangeability between tractors and trailers. The control unit is connected to the vehicle power supply via a two core cable with in-line fuse and filter to suppress electrical noise from the ignition system, etc. Once a tractor has been hitched to a given trailer and the connector 8, 9 made good, the microprocessor 14 of the conrol unit 10 is programmed by connecting a keypad 24 to the keypad interface 23 and setting in, for each channel which is to be used, upper and lower temperature limits, and also

recording delivery/driver number, vehicle number and data storage interval. In addition, a security code has to be entered before any programming is accepted.

With the trailer 1 illustrated in Fig. 1, each of the sections 3, 4 and 5 is allocated a channel of the control unit 10 and a further channel is allocated to the compressor unit 32 mounted on the trailer 1 and controlling the refrigeration of the latter. The compressor unit 32 has a defrost cycle and this is monitored by the control unit 10 via the control channel allocated thereto in that if a defrost cycle takes longer than a pre-programmed time, whereby the temperature in the trailer is likely to rise beyond the set upper limit, then an LED 33 marked DEFROST and located close to the display 16 flashes. At the same time, the malfunction is recorded for subsequent printing out.

Assuming that the trailer sections 3, 4 and 5 contain fresh, chilled and frozen food, respectively, then the upper and lower temperature limits are set accordingly and entered into the memory of the microprocessor 14. The data storage interval may range from 1 to 99 minutes for example, and the duration of display for each channel may be 10, 20 or 30 seconds as required by the operator. The channels which have been programmed are displayed sequentially and the display 16 can be frozen by operating the "hold" switch. The display 16 shows the channel number and the sensed temperature in degrees Centigrade associated therewith, negative temperatures being prefaced by a minus sign and positive temperatures being prefaced by a blank.

The temperature sensed by each sensor 6 is measured by the ADC 11 and fed as a digital signal to one of the RAMs 17 where it is stored until interrogated by the microprocessor and displayed on the display 16 at the predetermined interval. Should the temperature of any of the trailer sections 3, 4 and 5 fall below or exceed the limits set, then an alarm condition is initiated and this is stored in the other RAM 17 and the display for the or each alarmed channel will flash until the alarm condition has been removed. Thus the vehicle driver is continually updated as to the operating conditions within his trailer but more importantly, at the end of a journey the printer can be operated to provide a hard copy printout of the history of each programmed channel of the control unit against time (provided by the clock 19) so that if, for example, the printout should show that the frozen food section 5 was subjected to an excessively high temperature for too long a period of time, then the intended recipient of the goods may wish to refuse delivery. If more than one printout is required, then the printer only has to be operated again. Once printing is complete, the memory can be cleared by operating a RESET button although the programming remains until altered by reconnecting a keypad 24 to the keypad interface 23. Operation of the RESET button is ineffective before at least one printout has been obtained so tht no one can destroy the recorded data before a hard copy exists.

Fig. 4 shows part of a typical printout of recorded data and it will be seen that in the illustrated case four channels were rendered active with upper and lower temperature limits of −20°C and −55°C, respectively, for channels 1 to 3, and 0°C and −20°C for channel 4. The data storage interval was 15 minutes and the defrost (DEF) cycle time was 20 minutes. The run number and vehicle number were also recorded as well as the journey start and finish times.

The printout of Fig. 4 resulted from a trial run of the system and it will be seen that at the outset channels 1 to 3 show temperatures in excess of the respective upper limits, whereby the display would have flashed on channels 1 to 3 until the temperatures fell to below the upper limit which happened in channel 3 but not in channels 1 and 2. Channel 4 was within the set upper and lower limits at least for the first few hours which are shown in Fig. 4.

In one embodiment of the invention the memory available in the RAMs 17 is 4K and software numerical compression techniques allow the storage of 2048 temperatures and 1024 alarm situations. The amount of memory and the journey time (which may be several weeks) have to be taken into account in setting the data storage interval the memory also having to accommodate store alarm points and contact changes, i.e. door openings and closures.

The general operating system is based on a real event tasking programme. Tasks are performed at specific intervals; the controlling event is a one per second interupt fraom the RTC device. Display updates are performed every ten seconds and alarm, maximum, minimum and set point control functions are performed every minute. As already stated, data storage uses data compression techniques to provide maximum utilisation of available memory. In addition, the memory is shared over the number of active channels, providing for more efficient use of available data space. A simple on/off set point control facility is also provided. The software is structured to provide extra facilities very easily by inserting functions into unused time slots. The analogue readings do not have to be performed rapidly due to the inertia of the system. For example, the defrost processing section may or may not be included, depending upon on the type of refrigeration technique used.

Software has been developed using the modular principle. This allows different systems to be developed easily using existing modules and linking them with a different

operating environment. For example a module has been designed to recommend acceptance, rejection or need for consulation, on a load, based on specific parameters arranged in some form of 'decision matrix'.

The control unit 10 may be modified to suit different applications; for example a single RAM may be employed rather than two separate RAMs, and the clock 18 need not be separate from the microprocessor 14 although this is preferred as it relieves the latter of unnecessary complex interrupt driven software. Also, a separate printer external to the tractor 2 could be used.

The ADC 11 is a 3.5 digit binary coded decimal (BCD) device which is preferred because most ADCs have binary outputs which if used in the present invention would require conversion to decimal. Accordingly, the use of BCD device avoids this separate conversion and also a high speed ADC need not be employed.

In the illustrated embodiment, all of the components shown in Fig. 2 are housed in a single container located within the tractor cab for easy viewing by the driver. However, the various components can be split and located where convenient either within or exteriorly of the tractor cab.

It will be seen that the invention provides a very compact, efficient temperature monitoring system which is particularly well suited to refrigerated articulated vehicles in providing detailed information as to the temperature experienced by the storage compartment of the vehicle throughout a journey with there being no possibility of tampering with the record. However, the invention is applicable to many other situations such as, for example, container ships when the internal temperature of one or more containers needs to be held within limits, and stationary storage facilities where again the temperature needs to be controlled.

In application where the distance between the sensors and the control unit is relatively small, it would be possible to employ voltage proportional sensors instead of current proportional sensors. However, the latter are still preferred not only to avoid all risk of output degradation by electrical noise but also because they provide automatic spatial average of temperature which would otherwise require software techniques. This is because when two or more sensors are employed in a given space then if they are connected in parallel, advantage can be taken of Kirchoff's law which implies that if *n* sensors are connected in parallel, the total current I_T is given by:–

$$I_T = i_1 + i_2 + i_3 + \ldots i_n \qquad (1)$$

The voltage V_T across the terminating resistor is thus:–

$$V_t = I_T \times R \qquad (2)$$

If R is replaced by R/n, the voltage becomes:–

$$\frac{V_T}{n} = \frac{I_T \times R}{n}$$

Substitution of equation of I_T by equation (1) shows that this is the arithmetic average of the currents and hence of the temperatures sensed by each sensor. This facility permits the use of non-standard resistor values which can be compensated by the gain of the ADC 11.

Conditions in additions to temperature may be monitored utilising a system in accordance with the present invention. For example, humidity may be monitored by locating an humidity sensor in the container, or in one or more compartments thereof, the or each sensor being connected by a cable to the connector 8/9 in the illustrated embodiment and thence to the multiplexer 12 and the ADC 11. If humidity is to be controlled as well as monitored, a spray may be mounted in the or each compartment, each spray being rendered operative by a control device connected to an output line 31 of the input/output device 28. Thus if a compartment becomes too dry, the spray control device is activated and the compartment sprayed with water to increase the humidity.

A static version is a logical development of the mobile version and illustrates the versatility of the system design in general. The system has the ability to interface to a proprietary modem for communication over the public switched telephone network (PTSN). The static version functions as an alarm reporting system and a general monitoring and control version is retained, but in addition other features—such as entering a number of telephone numbers—may be included. In hardware terms the only differences between the static and mobile versions are external—the connection of a standard auto/dial modem, and the addition of an external mains power supply, including a float charged battery for use in the event of a mains failure. The whole system may be housed in a standard enclosure.

A serial communications interface which is provided in the mobile version can be utilised for modem control on the static version.

In general terms, the static system will monitor the temperature of a plurality, such as eight, channels continuously, reporting any preset alarm conditions, i.e. out-of-range temperatures, via the PSTN. This is implemented via an auto-dial modem, which can communicate with an auto-answer modem at a preset number. Upon receipt of the call an appropriate message would be passed from the sys-

tem to the dialled address being displayed upon a miniature printer.

The use of modular software with the hardware features available in the system make the system a flexible tool with with ranging applications, not only in it's original field of air temperature measurements, but also in the monitoring of humidity, flow or pressure, via suitable tranducers.

CLAIMS

1. A temperature monitoring system for a temperature controlled container comprising one or more temperature sensors mounted so as in use to sense the temperature of the interior of the container and operable to produce an electrical signal representative of the sensed temperature, and data logging means responsive to said electrical signals to log the temperature history of the container over a period of time for subsequent retrieval.

2. A system according to claim 1, wherein the data logging means is in the form of a memory means operable to calculate and store the temperatures sensed by the or each temperature sensor, and wherein analogue-to-digital converter means are connected between the or each sensor and the memory means.

3. A system according to claim 1 or 2, wherein display means are provided for displaying the temperature sensed by the or each sensor, and wherein alarm means are also provided to warn when a temperature or range of temperatures has not been met or has been exceeded.

4. A system according to claim 3, wherein printer means are connectible to the data logging means and are operable to provide a hard copy of the temperature history of the container.

5. A system according to any of the preceding claims, wherein the or each sensor is of the current proportional type, whereby the electrical resistance of any electrical leads extending between the sensors and the data logging means does not affect the accuracy of the sensor output signal.

6. A system according to claim 5, wherein two or more sensors are connected in parallel so as to provide a direct spatial average of the temperature of the region of the container in which the sensors connected in parallel are disposed.

7. A system according to any of the preceding claims and comprising a plurality of channels, whereby a plurality of sections of the container can be monitored independently.

8. A system according to claim 7, wherein one channel is arranged to monitor a defrost cycle for the container which if exceeded is recorded by the data logging means.

9. A system according to claim 8, wherein alarm means are provided for warning when the defrost cycle time has been exceeded.

10. A system according to claim 8 or 9, when appended to claim 3, wherein the temperature of each channel is displayed sequentially on the display means and wherein the display is arranged to flash on each channel in connection with which an alarm condition has been sensed.

11. A system according to claim 10, wherein the display can be held for a selected channel.

12. A system according to any of the preceding claims, wherein the system is controlled by a microprocessor which is programmable externally.

13. A system according to any of the preceding claims and further comprising a real time clock.

14. A system according to claim 3 and any claim appended thereto, wherein RESET means are provided but which is arranged to be ineffective until at least one printout of the recorded data has been effected, whereupon the recorded data is erased on operation of the RESET means.

15. A system according to any of the preceding, and further comprising a digital input/output device for monitoring and control purposes.

16. A system according to any of the preceding claims and further including one or more humidity sensors operable to sense the humidity within the container, the or each humidity sensor being operable to produce an electrical signal representative of the sensed humidity, which signals are coupled to the data logging means.

17. A system according to claim 16, and further including spray means mounted within the container and actuatable when the humidity falls below a predetermined value.

18. A temperature monitoring system for an articulated refrigerated vehicle substantially as herein particularly described with reference to the accompanying drawings.

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